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(54) THERMAL POWER PLANT

(71) We, AKTIEBOLAGET ATOMENERGI of Liljeholmsvagen 32, Stockholm, Sweden, a joint stock company organised according to the laws of Sweden, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a thermal power plant.

We describe below a thermal power plant comprising: a gas turbine; an electric generator arranged to be driven by the gas turbine; a compressor adapted to generate compressed air; a chamber adapted to receive compressed air from the compressor and deliver compressed air to the gas turbine; a reservoir for water located at a higher level than the chamber and a conduit between the reservoir and the chamber through which water is arranged to be led from the reservoir to the chamber while air is being discharged from the chamber and in the opposite direction while the chamber is being charged with air. The compressor may be driven by the gas turbine but alternatively it may be driven by a separate motor. The latter is advisable if the thermal power plant is intended to be in operation only during periods of peak load, in which case the compressor can be driven continuously, or only during periods of low load.

In such a thermal power plant, the chamber could well comprise a rock chamber which is located at such a great depth that the static pressure obtained due to the level difference between the reservoir and the rock chamber corresponds to the required air pressure; but such a rock chamber would tend to be extremely expensive since it must be located at such a great depth.

We shall describe how we can provide a thermal power plant in accordance with this invention where such a rock chamber only need be located at a reasonable depth below the reservoir but which may contain compressed air having a pressure which is at least twice as high as, and preferably several times higher than, the static pressure corresponding to the difference in level between the chamber and the reservoir. In our preferred thermal power plant the chamber has only been blasted at such a depth that the rock above is sufficiently strong to withstand the high air pressure. For example, for an air pressure of 80 atmospheres it is sufficient if the highest point of the rock chamber is located at a depth of 100 m, as against 800 m which would otherwise be required.

Thus increased pressure in the rock chamber can be achieved by arranging a pump in the conduit connecting the reservoir to the rock chamber. When air is being discharged from the chamber, the pump is arranged to maintain the pressure in the chamber at a considerably higher level than the static pressure which can be obtained due to the level difference between the reservoir and the chamber.

Accordingly, the present invention provides a thermal power plant, comprising: a gas turbine; an electric generator arranged to be driven by the gas turbine; a compressor adapted to generate compressed air, as hereinafter defined; a chamber adapted to receive compressed air from the compressor and to deliver compressed air to the gas turbine; a reservoir for water located at a higher level than the chamber; and a conduit between the reservoir and the chamber through which water is being discharged from the chamber and in the opposite direction while the chamber is being charged with air, the conduit containing a pump adapted to keep the pressure in the chamber while air is being discharged therefrom considerably higher than the static pressure which can be obtained due to the level difference between the reservoir and the chamber.

The invention is described hereinafter with reference to the use of a compressed air chamber. As will be readily understood, the power plant described in detail herein-

after could readily be operated with an alternative working gas being compressed. Accordingly, the word "air" as used in this specification, and in particular as used in the claims, is to be taken to include not only atmospheric air but also any alternative usable working gas or mixtures thereof.

As will be clear from the arrangements described in detail below, when air is being discharged from the compressed air chamber, therefore, energy must be sacrificed in order to pump water into the compressed air chamber. However, we have found that this energy loss is more than compensated by the advantage gained by being able to locate a rock chamber higher up, or by a rock chamber of a certain size and at a certain depth being able to hold a considerably larger mass of air than if only the natural difference in level between the reservoir and the rock chamber had been utilized. The loss in energy due to the operation of the pump can be partially recovered by permitting water which, when the compressed air chamber is being charged, flows to the reservoir under pressure drop to drive a turbine which in turn drives an electric generator, for example. Alternatively the water turbine may be connected to the shaft of the compressor so that it provides some of the power necessary to operate the compressor. The pump and the water turbine may be placed in separate branches of the water conduit. Another alternative is for the pump to be arranged so that it can operate as a water turbine. In this case the water conduit need only include a reversible turbine-pump unit. By means of a first coupling this turbine-pump unit can be connected to an electric motor and by means of a second coupling it can be connected to an electric generator. As already mentioned the pump may be driven by an electric motor. Alternatively the pump may be arranged on the same shaft as the gas turbine and thus be driven by this.

In the following description of preferred embodiments the invention will be explained more fully with reference to the accompanying drawing in which, in simplified form, Fig. 1 shows an embodiment of thermal power plant constructed according to the invention, and Fig. 2 shows part of an alternative embodiment also constructed according to the invention. In order to facilitate an understanding of the drawings the flow directions in the conduits have been indicated by arrows of two different types. Arrows of type 16 (see Fig. 1) show the flow during periods of peak load and arrows of type 17 show the flow during other periods. The thermal power plant comprises a gas turbine 15 consisting of a plurality of turbine stages 7 connected to a common shaft, each turbine stage having its own combustion chamber 6. Compressed air flowing to the turbine is led in turn through the various turbine stages, thus exploiting the high pressure of the compressed air to the full. The exhaust from the last stage of the gas turbine is led through a regenerative heat exchanger 13 where it can heat incoming compressed air. Due to the high pressure of the compressed air, this pre-heating results in a considerable increase in the efficiency for a limited extra initial outlay in cost. The gas turbine 15 is arranged to drive an electric generator 8.

The compressed air is generated in a compressor 18 comprising a plurality of compressor stages 4 driven by a common motor 5 which may be an electric motor. Between the various stages and after the final stage, (coolers 9 are arranged.

A compressed air chamber 1, which is preferably a rock chamber, is arranged for the storage of the compressed air. A conduit 2 extends from the bottom of the compressed air chamber up to a water reservoir 3, which is preferably a lake. The conduit 2 is divided into two branches 21, 22 in the Fig. 2 arrangement, the branch 21 containing a valve 19 and a pump 10, which is driven by a motor preferably electric (not shown), the branch 22 containing a water turbine 11 arranged to drive an electric generator 14; the water turbine 11 being connected to the shaft of the compressor 18 by means of a coupling 42 and the pump 10 being connected to the shaft of the gas turbine 15 by means of a coupling 43.

The conduit 2 also includes a flow gauge 23 (see Fig. 1) and a valve 12 actuated by this gauge. If, due to pipe rupture, the flow rate of the water in the conduit 2 exceeds a predetermined maximum permitted rate, the valve 12 will close.

Alternatively, the pump and water turbine of the Figure 2 arrangement may be replaced by a reversible turbine-pump unit 40. By means of a first coupling 52 this turbine-pump unit 40 can be connected to an electric motor 55 and by means of a second coupling 53 it can be connected to an electric generator 56.

The compressed air chamber 1 is in communication with the preheater 13 and the gas turbine 15 through a conduit 24. The high pressure side of the compressor 18 is in communication with the conduit 24 through a conduit 25.

The thermal power plant illustrated operates in the following manner: At a time when there is maximum demand for electricity, the compressor 18 is turned off and the gas turbine 15 started, whereupon compressed air is taken from the chamber 1. A substantially constant air pressure is maintained in this chamber by water being sup-

plied from the water reservoir 3 through the pump 10 and conduit 2.

When the peak load period is over the gas turbine 15 is turned off and the compressor 18 started, whereupon the compressed air generated is led to the compressed air chamber 1 which is thus charged. The water forced out of the compressed air chamber is led to the water reservoir 3 through the conduit 2 and the water turbine 11, in which the drop in pressure of the water is exploited to generate electric energy in the generator 14.

Instead of the internal combustion in the combustion chambers 6, the compressed air may be heated in heat chambers which are heated externally, for example by means of oil or by a hot heat medium which has been heated in a nuclear reactor in which it acts as coolant.

The heat obtained from the coolers 9 can be utilized in various ways. For example it may be used in a district heating plant for residential heating or in an evaporation plant for converting salt water to fresh water. In order to be able to provide a heat consumer 31 with a continuous supply of heat, some of the heat from the coolers 9 is preferably permitted to heat the water in a hot water accumulator 30 from which heat can be taken while the compressor 18 is out of operation. The flow of water from the compressor 18 to the accumulator 30 and the heat consumer 31, respectively, is controlled by valves 32, 33, 35, 36, 37, 38 and a pump 34.

In an alternative embodiment the generator 8 and the motor 5 may comprise a motor-generator unit which can be run alternately as generator and motor. This unit is then connected to the gas turbine 15 and the compressor 18 by means of couplings so that it can be connected to one or other of these machines as desired.

WHAT WE CLAIM IS:—

1. A thermal power plant, comprising: a gas turbine; an electric generator arranged to be driven by the gas turbine; a compressor adapted to generate compressed air, as hereinbefore defined; a chamber adapted to receive compressed air from the compressor and to deliver compressed air to the gas turbine; a reservoir for water located at a higher level than the chamber; and a conduit between the reservoir and the chamber through which water is being discharged from the chamber and in the opposite direction while the chamber is being charged with air, the conduit containing a pump adapted to keep the pressure in the chamber while air is being discharged therefrom considerably higher than the static pressure which can be obtained due to the level difference between the reservoir and the chamber.

2. A thermal power plant according to Claim 1, wherein the conduit also contains a turbine which is arranged to be driven by the water which, when the chamber is being charged with air, flows from the chamber to the reservoir.

3. A thermal power plant according to Claim 2, wherein the water turbine is connected to the shaft of the compressor.

4. A thermal power plant according to any of Claims 1—3, wherein the conduit includes a shut-off valve and a flow gauge which actuates the shut-off valve, said flow gauge being arranged to close the shut-off valve when the flow rate in the conduit reaches a maximum permitted value.

5. A thermal power plant according to any of the preceding claims, wherein the gas turbine comprises several turbine stages, each turbine stage being provided with a combustion chamber or some other heat source.

6. A thermal power plant according to any of the preceding claims, wherein the compressor comprises a plurality of compression stages as well as a cooler after each compression stage.

7. A thermal power plant according to Claim 6, wherein the coolers are connected to a heat consumer.

8. A thermal power plant according to Claim 7, wherein the coolers are also connected to a heat accumulator so as to permit a continuous supply of heat to the heat consumer.

9. A thermal power plant according to Claim 2 or any claim appendant thereto, wherein the pump and the water turbine consist of a reversible pump-turbine unit.

10. A thermal power plant according to any of the preceding claims, wherein the pump is connected to the shaft of the gas turbine.

11. A thermal power plant substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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Fig. 1

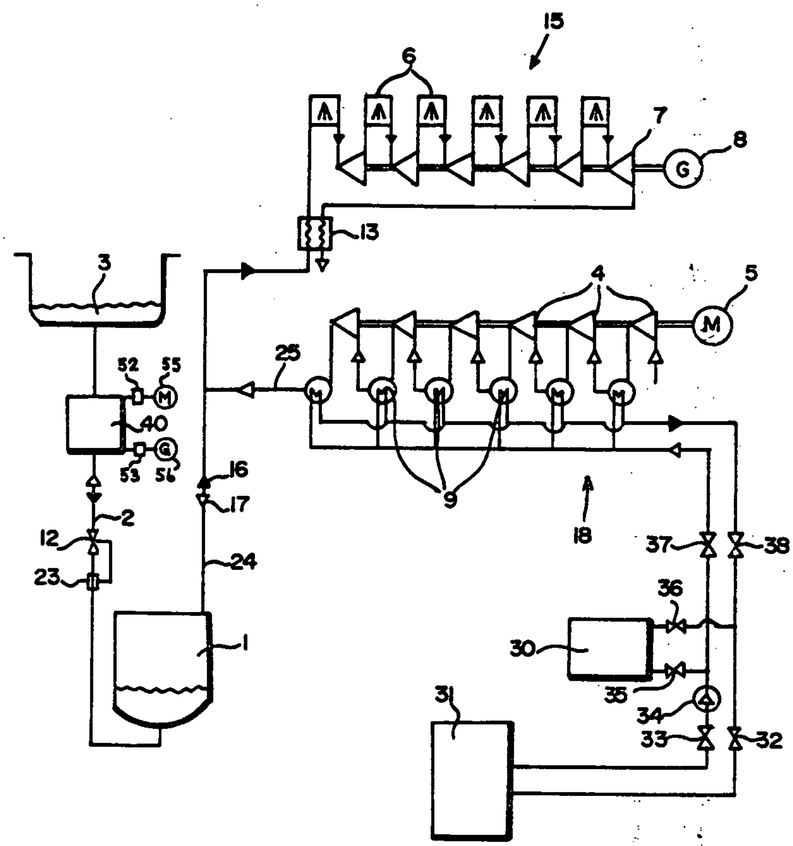
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Fig. 2